Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period: \_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_\_\_\_\_\_

**Introduction to Half-Life and Radioactive Decay**

**Bill Nye and Radioactive Decay**

1. According to the scientist interviewed, plutonium is the most dangerous thing humans have ever made. He also thinks it will probably be our demise. A \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of an ounce the size of a speck of dust, if inhaled, will cause lung cancer. A few pounds the size of a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ will bring down a city if used in a nuclear weapon.
2. We measure radioactivity in \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
3. The atoms in radioactive material spontaneously just break apart, or \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
4. We can’t tell when an \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ atom will decay, but we can tell when a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of them will.
5. A half-life is the amount of time it takes \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

1. Plutonium has a half-life of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ years. After ten half-lives, or \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ years, the water starts to look pretty clear.
2. Plutonium is \_\_\_\_\_\_\_\_\_\_ million times more radioactive than uranium dug from a mine.

**Hunting the Elements: Radioactive Decay of Carbon-14**

1. How many isotopes of carbon are there?
2. What are the similarities and differences of the isotopes of carbon?
3. About \_\_\_\_\_\_\_% of carbon atoms have an extra neutron, giving them seven (carbon-13), whereas about \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ carbon atoms have eight neutrons, giving them 14 (carbon-14). Carbon-14 is a crucial tool for “unlocking the past.”
4. Scientist Scott Stine studies how often droughts occur and how long they last in California. He uses \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ to date the trees in order to find out how long ago droughts occurred.
5. Unlike the other natural isotopes of carbon, carbon-14 is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. Over time, one of its \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ turns into a proton and spits out an electron. Now with seven protons instead of six, it turns into \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. This process is called radioactive decay.
6. Scientists know how long it will take for any amount of carbon-14 to decay. Scientists call that time its \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
7. Living things constantly replenish the carbon in their bodies, but after death that process \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. The amount of carbon-12 stays the same, but the amount of carbon-14 decays at a constant rate, making carbon-14 a “\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.”

**Half-Life Lab Background**

If two nuclei have different masses, but the same atomic number, those nuclei are considered to be isotopes. Isotopes have the same chemical properties, but different physical properties. An example of isotopes is carbon, which has three main isotopes: carbon-12, carbon-13 and carbon-14. All three isotopes have the same atomic number of 6, but have different numbers of neutrons. Carbon-14 has 2 more neutrons than carbon-12 and 1 more than carbon-13, both of which are stable. Carbon-14 is radioactive and undergoes radioactive decay.

Radioactive materials contain some nuclei that are stable and other nuclei that are unstable. Not all of the atoms of a radioactive isotope (radioisotope) decay at the same time. Rather, the atoms decay at a rate that is characteristic to the isotope. The rate of decay is a fixed rate called a half-life.

The half-life of a radioactive isotope refers to the amount of time required for half of a quantity of a radioactive isotope to decay. Carbon-14 has a half-life of 5,730 years, which means that if you take one gram of carbon-14, half of it will decay in 5,730 years. Different isotopes have different half-lives.

The ratio of the amounts of carbon-12 to carbon-14 in a human is the same as in every other living thing. After death, the carbon-14 decays and is not replaced. The carbon-14 decays, with its half-life of 5,730 years, while the amount of carbon-12 remains constant in the sample. By looking at the ratio of carbon-12 to carbon-14 in the sample and comparing it to the ratio in a living organism, it is possible to determine the age of a formerly living thing. Radiocarbon dates do not tell archaeologists exactly how old an artifact is, but they can date the sample within a few hundred years of the age.

**Pre-Lab Questions (answer in complete sentences)**

1. Define half-life.
2. What is carbon-14’s half-life? If you have 20 grams of carbon-14, how long will it take until you have only 10 grams?
3. How can scientists determine the age of a formerly living thing using carbon dating?
4. How accurate is carbon dating?

**Lab Objectives**

* To define the terms half-life and radioactive decay
* To observe the exponential nature of radioactive decay
* To create line graphs from collected data
* To compare data
* To understand how radioactive decay is used to date archaeological artifacts

**Procedure**

1. Put 10 M&M’s® candies of any color into a zip lock bag. Each group is starting with 10 M&M’s® candies, which is recorded as Trial 0 in the data table. All of the M&M’s® candies are radioactive.
2. Shake the bag and spill out the candies onto a flat surface.
3. Pick up ONLY the candies with the “m” showing - these are still radioactive. Count the “m” candies as you return them to the bag.
4. Record the number of candies you returned to the bag under the next Trial.
5. Move the candies that are blank on the top to the side - these have now decayed to a stable state.
6. Repeat steps 2 through 5 until all the candies have decayed or until you have completed Trial 7.
7. Record the results for the other groups and total all the Trials.

**Data Table**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Results | Trial 0 | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Trial 6 | Trial 7 |
| Group 1 | 10 |  |  |  |  |  |  |  |
| Group 2 | 10 |  |  |  |  |  |  |  |
| Group 3 | 10 |  |  |  |  |  |  |  |
| Group 4 | 10 |  |  |  |  |  |  |  |
| Group 5 | 10 |  |  |  |  |  |  |  |
| Group 6 | 10 |  |  |  |  |  |  |  |
| Group 7 | 10 |  |  |  |  |  |  |  |
| Group 8 | 10 |  |  |  |  |  |  |  |
| Totals | 80 |  |  |  |  |  |  |  |

1. Plot the total results on a graph with number of candies on the vertical axis and trial number on the horizontal axis. Is the result a straight or a curved line? What does the line indicate about the nature of decay of radionuclides?



1. Do the number of atoms you start with affect the outcome? Explain.
2. Did each group get the same results? Why or why not?
3. Did any group still have candies remaining after Trial 7?
4. Why do the totals for all groups better show what happens during half-life rather than any one group’s results?
5. What happens to the total number of candies with each trial (half-life)?

**Half-Life Calculations**

|  |
| --- |
| *Formula for calculating the amount of radioactive material remaining:* |

**First type of problem:**

1. Fluorine-21 has a half-life of approximately 5 seconds. What fraction of the original nuclei would remain after 60 seconds?
2. Iodine-131 has a half-life of 8 days. What fraction of the original sample would remain at the end of 32 days?
3. Chromium-48 decays. After 6 half-lives, what fraction of the original nuclei would remain?

**Second type of problem:**

1. The half-life of chromium-51 is 28 days. If the sample contained 510 grams, how much chromium would remain after 56 days?
2. Actinium-226 has a half-life of 29 hours. If 100 mg of actinium-226 disintegrates over a period of 58 hours, how many mg of actinium-226 will remain?
3. The half-life of Po-218 is three minutes. How much of a 2-gram sample remains after 15 minutes?